

Treating Displaced Distal Forearm Fractures in Children

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Abstract

Purpose: Distal forearm fractures are among the most common fractures in children. In the past few years the option of percutaneous pinning has gained more attention in the treatment of unstable fractures. However, it remains unclear in which cases a fracture or its reduction should be considered unstable.

Study Design: In order to evaluate which type of fractures profit most from additional pinning after closed reduction, we performed a retrospective analysis of 225 consecutive cases using the recently published AO pediatric classification of long bone fractures.

Results: After closed reduction, position in the cast was lost in 23% of the cases. The proportion of unstable reductions was much higher in completely displaced fractures. The amount of dislocation was more important than the type of fracture according to the AO classification proposal.

Conclusions: Fully displaced fractures should always be reduced in a setting with pins immediately available. If anatomical reduction cannot be achieved, pinning is advocated. The AO proposal for pediatric long bone fracture classification could be a useful tool to render the diverse studies more comparable. However, the important feature of complete versus subtotal displacement is lacking.

Key Words

Children · Fracture · Distal forearm · AO pediatric classification

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Introduction

Distal forearm fractures are the most common fractures at any age. While treatment of displaced fractures in adults has changed more towards operative management, closed reduction and splinting is still the most used treatment option in children. If and in which cases there is an indication for operative management is still under discussion.

There is no agreement in the literature on how much displacement of forearm fractures in children can be accepted and left to normal remodelling. Von Laer reports that dorsal displacements up to 40° will remodel in children under the age of 10 years [1]. Even so some authors suggest reposition at displacements as low as 15° under the age of 10 years and 10° for older children [2, 3]. Others accept up to 20° angulation at any age [4, 5] (Table 1). The fact that the long-term result is determined by the position at fracture consolidation and that loss of position in the cast may be more important than the initial displacement [6], makes it difficult to establish rules. Additionally, comparing different studies is problematic because so far there is no clear definition of the metaphysis in the child. The recently published AO proposal of pediatric long bone fracture classification may help to overcome this problem [7].

However, there is an agreement that repetitive treatment should be avoided because the need for repetitive manipulation is known to be associated with an augmented number of growth disturbances [5, 8]. Nevertheless, remanipulation rates of 20–39% are reported [4, 9–13], with one study showing a redisplacement rate of 90% in isolated radius fractures [2].

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Table 1. Summary of relevant studies.

| Author | Nr. pat | Age | Indication for primary reduction | Sec. man. (%) | Factors for sec. displacement | Not significant factors |
|-----------------|---------|--------------|---|---------------|--|--|
| Proctor [4] | 68 | <16 | >20° | 24 | Complete displacement Failure to achieve perfect reduction | Age Site of fracture Initial angulation Experience of surgeon |
| Mani [10] | 94 | <13 | >20° (?) | 22 | Complete displacement (>1/2 diameter) Volar angulation | Age Initial angulation |
| Miller [11] | 34 | >10 <14 | >30° dorsal | 39 | Complete displacement | Not mentioned |
| Haddad [9] | 86 | 4–16 | >15° | 21 | Complete displacement Lack of anatomical reduction Experience of surgeon | Age Type of Immobilization Ulnar involvement Angulation |
| Houshian [17] | 85 | <15 | Only E2 fractures | 3 | Not mentioned | Not mentioned |
| Zimmermann [8] | 30 | | >20° at any age | | Not mentioned | Not mentioned |
| McLauchlan [12] | 68 | 4–14 | Complete displacement | 21 | Not mentioned | Surgeon's experience |
| Gibbons [2] | 23 | <10 10–15 | >10° >15° | 91 | Isolated radius fracture | Not mentioned |
| Zamzam [13] | 183 | | Only isolated radius fractures Not mentioned | 25 | Complete displacement Ulna fracture | Non anatomical reduction |

The factors influencing redisplacement are not well known. Complete displacement and failure to achieve perfect anatomical reduction are important [4, 9–11]. Other reasons mentioned are isolated fracture of the radius, not well fitting casts, and experience of the surgeon [2, 9, 14].

While it is quite clear that percutaneous pinning can effectively reduce the risk for secondary displacement [12, 15, 16], it is not known which fractures will profit from this method and in which cases this may be an overtreatment. McLauchlan advocates pinning in all fully displaced fractures [12]. Choi limits the indication to displacements of more than half of the diameter [15]. Gibbons suggests pinning in isolated radius fractures [2]. Proctor recommends pinning of all fractures where anatomical reduction cannot be achieved [4]. Mani indicates “severe fractures” with “inadequate reduction” as candidates for K-wires. Most studies are, however, performed with too few patients to perform subgroup analysis of fracture type.

To investigate which distal fractures are prone to secondary dislocation, we retrospectively analyzed all manipulated distal forearm fractures at our clinic over a period of 2 years.

Patients and Methods

Patients

All cases of children with distal forearm fractures presented at our emergency department between January 1st 2004 and December 31st 2005 were analyzed. All patients needing reduction or operation were included in the study and their X-rays reviewed. Patients with pathological fractures and patients initially treated at an outside facility were excluded. Patients who had only X-rays at the outside facility but manipulation at our institution were included.

Fractures

Patients with epiphyseal and metaphyseal fractures where included in the study. A metaphyseal fracture was defined as a fracture within a square over the epiphyseal plate of both bones on the AP-X-ray according to the AO proposal [7] (Figure 1).

Treatment

The initial treatment option was chosen by the emergency physician/surgeon on duty according to our internal guidelines:

Distal forearm fractures with more than 20° angulation in a child younger than 10 years and any



Figure 1. Definition of the metaphysis.



Figure 2. AO Classification: *E1*: physeal injury with complete separation of epiphysis (Salter Harris type I); *E2*: physeal injury with metaphyseal fragment (Salter Harris type II); *M2*: incomplete metaphyseal fracture (One broken corticales); *M3*: Complete metaphyseal fracture (two broken corticales).

angulation in older children were considered an indication for reduction.

Depending on the age of the child and his or her preference, general anesthesia or regional (IV) anesthesia was chosen for the reduction.

If the fracture was not stable under fluoroscopic control after reduction, two diverging K-wires were percutaneously inserted radially. Follow-up X-rays were obtained 5 and 10 days later in non-operated patients and at 3 weeks and 3 month in all patients. If a redisplacement was noted on day 5 or day 10 X-ray controls, the decision for re-reduction and radial K-wire fixation was judged by the same criteria as in the post accident X-ray.

After reduction, fractures were immobilized in an above-elbow cast, either with a plaster of Paris or a Scotchcast® (3M, Minnesota). The plaster of Paris was arranged as a sandwich of a volar and a dorsal splint, unified by a paper and an elastic bandage. The Scotchcast® was applied as a mixed soft-scotch cast with a dorsal and a volar splint of Scotchcast® unified by a circular layer of Softcast®. The type of plaster and the position of the wrist in the plaster (flexion, neutral or extension) were chosen by the physician on duty.

Analyzed Parameters

Radius and ulna fractures were classified separately according to the AO proposal [7] with additional denomination of the radius fractures as fully or non-fully displaced (Figure 2). The angulations in the sagittal and frontal plane as well as the lateral translation

were measured on the initial and post reduction X-rays. Anatomical reposition was defined as no angulation and no translation in any direction.

Re-displacement was defined as the need for a secondary reposition and consecutive operation.

Statistics

Data were analyzed with Vassar Stats website for statistical computation using two-sided Chi-Square and Fisher's Exact Test where appropriate. A $p < 0.05$ was regarded as significant difference.

Results

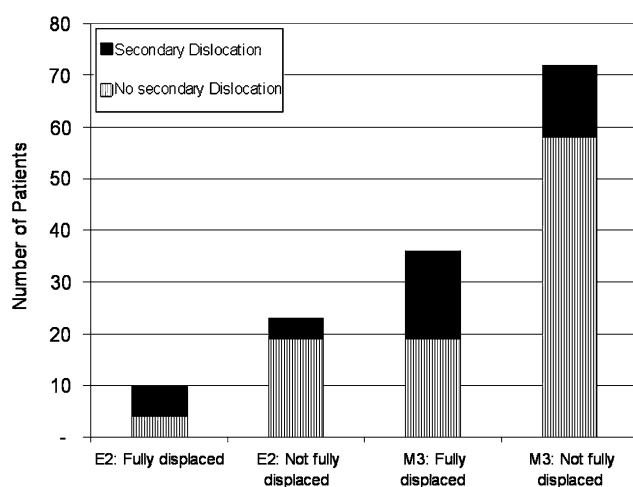
A total of 241 patients with 244 distal fractures were treated over the 2 years period at our institution. Three patients suffered simultaneous fractures of both arms. Due to their small numbers, for the statistical analysis, they were regarded as independent fractures. Nineteen fractures were excluded from the statistical analysis; 11 of them were initially treated at an outside facility, two had pathologic fractures, and the X-ray dossiers of six patients were not complete. Of the remaining 222 patients with 225 fractures 184 had metaphyseal fractures and 41 had physeal fractures Salter-Harris type I or II. There were no Salter-Harris type III or IV fractures of the radius in our collective. Ipsilateral humerus fractures were observed in four cases.

Patients' Demographics

Seventy-five patients were girls, 150 boys. The left arm was involved in 128 cases, the right 97 times. Mean age

Table 2. Overview of the results split by AO classification.

| AO class. | Total | Primary operation | Primary reduction | Secondary operation | Redislocation rate (%) |
|-----------|-------|-------------------|-------------------|---------------------|------------------------|
| E1 | 8 | 0 | 8 | 0 | 0 |
| E2 | 33 | 0 | 33 | 10 | 30 |
| M2 | 60 | 4 | 56 | 6 | 11 |
| M3 | 124 | 16 | 108 | 31 | 29 |
| Total | 225 | 20 | 205 | 47 | 23 |

**Figure 3.** Fully versus not fully displaced fractures; split by AO classification.

was 10 years (3–16). In 180 cases the fracture was displaced dorsally, in 45 cases palmarly.

Secondary Dislocation Rate

Of the included 225 fractures, 20 were operated immediately and 205 were initially reduced. Of the initially reduced patients 47 (23%) had a secondary displacement which needed a secondary operation. In three cases an external fixator was used and in one case internal fixation with a plate was performed. All remaining patients underwent percutaneous pinning. None of the 67 primary or secondary pinned patients needed reintervention because of redislocation.

Subgroup Analysis

See Table 2 and Figure 3.

E1. There were no full displacements among the eight E1 type fractures. All of them could be anatomically reduced and secondary displacement was never observed.

E2. All 33 patients suffering an E2 type fracture were primary reduced and none initially operated. The position was lost in 10 (30%) of these patients.

If an anatomical reduction was achieved (14 cases) the position in the cast was always maintained. In the 19 fractures where anatomical reduction could not be achieved, the position in the cast was lost ten times (53%) ($p < 0.05$).

Full displacement was noted in 10 out of the 33 cases. Redisplacement occurred six times (60%), all after non-anatomical reduction. Of the 23 not fully displaced fractures only four (19%) needed a secondary reduction, although in thirteen cases anatomical reduction had not been achieved ($p < 0.05$).

M2. An M2 type fracture was diagnosed 60 times. Of them, four were initially pinned and 56 initially reduced. Anatomical reduction was possible nine times and redislocation never occurred. Though an anatomical reduction was not achieved in 47 cases, a secondary intervention was necessary only six times (13%) ($p = 0.57$).

M3. In 124 patients a M3 type fracture was observed. A primary operation was performed in 16 cases and a primary reposition in 108 cases. A total of 31 (29%) patients showed secondary displacement.

Of the 108 primary reduced fractures, 36 were initially fully displaced. Of them 17 (47%) redislocated opposed to 14 out of 72 (19%) initially not fully displaced fractures ($p < 0.05$).

Anatomical reduction was possible in 16 cases with one secondary displacement (6%). In the 92 cases without anatomical reduction, redisplacement was observed in 30 cases (33%) ($p < 0.05$).

Risk Factors for Secondary Displacement After Primary Reduction

Degree of Dislocation (Table 3)

Of the 46 fully displaced and reduced fractures, 23 (50%) had to undergo a secondary operation as compared to 24 (15%) of the 159 not fully displaced fractures ($p < 0.001$).

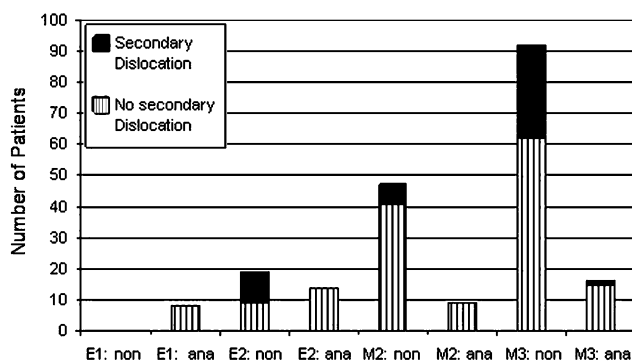
Angle and Direction of Dislocation

Reintervention was required after 39 (24%) of 162 dorsally displaced fractures, versus eight (19%) of the 43 palmarly displaced fractures. This difference was, however, not significant ($p = 0.54$).

Neither the angle of dislocation in the frontal or sagittal, nor the lateral dislocation showed any significance.

Table 3. Summary of major risk factors in primary reduced fractures.

| | Total | Secondary operation | Re-dislocation rate (%) |
|--|-------|---------------------|-------------------------|
| Complete displaced fracture | | | |
| Anatomical reduction | 7 | 1 | 14 |
| Non anatomical | 39 | 22 | 56 |
| Not complete displaced fracture | | | |
| Anatomical reduction | 40 | 0 | 0 |
| Non anatomical | 119 | 24 | 20 |

**Figure 4.** Influence of anatomical reduction (ana: Anatomical reduction; non: Non anatomical reduction).

Involvement of the Ulna

Overall, 118 patients had an additional ulna fracture, 15 of them underwent primary operation. After primary reduction, 29 (28%) of 103 showed a secondary dislocation.

Instable ulna fractures (ulna M3) resulted in a dislocation in 15 out of 39 cases (38%), compared to 12 out of 60 (20%) stable ulna fractures (ulna M2) ($p < 0.05$).

An isolated radius fracture existed in 107 patients of which five were initially operated. A secondary dislocation occurred in 18 (18%) of 102 patients after primary reposition ($p = 0.07$).

E2. Involvement of the ulna was present in eleven patients with E2 type fractures; a secondary intervention was needed three times (27%). An isolated radius fracture existed in 22 cases; six (27%) of them had to undergo a second procedure ($p = 0.46$).

M2. A redislocation was noted in three (13%) out of 23 patients with an additional ulna fracture. Secondary dislocations occurred in two (6%) out of 32 cases where no ulna fracture existed (32 cases) ($p = 0.65$).

M3. Patients with an M3 type fracture suffered an additional ulna fracture in 68 cases. In 22 (32%) of them, a secondary dislocation was noted compared to nine (23%) of the 40 patients with isolated radius fractures ($p = 0.32$).

Anatomical Reduction

Anatomical reduction could be achieved in 47 patients; one (2%) of them needed a secondary intervention. In the 158 patients where anatomical reduction could not be achieved, reintervention was needed in 46 patients (29%) ($p < 0.001$) (Figure 4).

Cast and Position in the Cast

In the 79 cases where a plaster of Paris was applied, redisplacement occurred 20 times (25%). If a Scotch-cast® was used (126 cases), redisplacement occurred 27 times (21%) ($p = 0.51$). In 104 cases the wrist was casted in a flexed position. A redisplacement was diagnosed in 16 (15%) of them. A neutral position was chosen 66 times and redisplacement noted in 17 cases (26%). After applying a cast with the wrist in extended position two (11%) out of 18 redislocated ($p = 0.10$).

Age

A secondary dislocation occurred in 23 (27%) out of 84 children under the age of 10 compared to 24 (20%) out of 121 children over 10 years of age ($p = 0.20$).

Discussion

A few prospective studies about the pinning of distal forearm fractures in children [11, 12] have recently been published. However, all of them had a very limited number of patients. Even though our study was conducted retrospectively, the large number of patients allows for the extraction of results from subgroup analysis. It is also the first time that the new AO classification proposal was used for fracture classification. The fact that the AO classification is a proposal implies that it still has some limitations. In particular, the important distinction between fully and non-fully displaced fractures is missing in the classification.

In this study, the overall secondary dislocation rate was not high compared to other studies (Table 1). One reason may be, that only dislocations leading to an operation were considered for our study. Re-dislocations within our limits (same limits as for the initial decision for reduction) were not considered. The patient is not interested in angles; what matters for him are a good outcome, i.e. range of motion and how many times he has to undergo an intervention.

The limits of dislocation and angulation are arbitrary. Anything between 15° and 30° is found in the literature (Table 1). As proposed by other authors [4, 8, 10], we chose a limit of 20° to avoid a prolonged time of remodeling and visible angulation at the time of cast removal.

In accordance with other studies, complete displacement was a major risk factor for secondary displacement [4, 9, 10, 13]. If these fractures are anatomically reduced, the risk of secondary displacement can be minimized. However, this may be very difficult to accomplish in M3 type fractures where anatomical reduction could only be achieved in 3 out of 36 cases (8%). In completely displaced E2 type fractures, this goal could be achieved in 6 out of 10 patients (60%) ($p < 0.001$).

In contrast to the results presented by Gibbons [2], isolated radius fractures were less prone to secondary displacement than fractures of both bones. Especially instable fractures of the ulna (ulna M3) are significantly more prone to secondary dislocation. Exceptions to this finding were E2 fractures where isolated radius fractures were more prone to secondary displacement.

Dorsally displaced fractures had a higher tendency of secondary displacement than palmarly displaced ones. This may, however, be attributed to the higher energy normally involved in these fractures and therefore the higher number of fully displaced fractures. If fully and not fully displaced fractures are analyzed separately there is no difference.

In contrast to other studies, epiphyseal fractures were included in our analysis. Despite their small prevalence, E1 fractures seem to be unproblematic. In contrast, anatomical reduction appears to be crucial in E2 fractures. We cannot confirm the small number of secondary manipulations presented by Houshian [17] and the question remains if our indication for re-reduction is too rigorous in these cases.

The type of cast may be less important in the management of distal forearm fractures. Good results can be achieved either with Scotchcast® or Plaster of Paris. Tilting the wrist in the opposite direction of the fracture dislocation may offer an advantage. However, this finding was not significant in our study and randomized prospective studies are needed to clarify this question.

A retrospective study points out the fact that a below-the-elbow plaster may be advantageous for the treatment of these fractures [18]. At the beginning of our study, the evidence for this procedure was weak. Therefore, an above-the-elbow cast was chosen. It was thought that additional prevention of pro-/supination

could potentially lead to a better stability. Recently however, the efficacy of below-the elbow plaster has been supported by two prospective studies. Therefore, the application of short arm plasters should be considered in future studies.

Conclusions

Completely displaced distal forearm fractures should always be reduced in the disposition of pins. If anatomical reduction cannot be achieved, pinning is advocated.

If some additional features are included, the AO proposal of pediatric long bone fracture classification may become a useful tool to render different studies more comparable in the future.

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